

PRIZE ESSAY 25

ON

THE STEREOSCOPE.

BY

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LONDON:

PUBLISHED BY THE LONDON STEREOSCOPIC COMPANY,
54, CHEAPSIDE, AND 313, OXFORD-STREET;

AND

ARTHUR HALL, VIRTUE, AND CO., PATERNOSTER ROW.

—
1856.

PRINTED BY

THE STEREOGRAPHIC

WILLIAM G. LORIE, A.M., F.R.S.

LONDON: PRINTED BY J. JOHNSON, ST. PAUL'S CHURCH-YARD.

LONDON:

PUBLISHED BY THE LONDON STEREOGRAPHIC COMPANY,

IN GREAT-BRITAIN AND IRELAND.

AND

ARTHUR HALL, 11, FLEET STREET, AND 10, PATERNOSTER ROW.

AWARD OF SIR DAVID BREWSTER.

TO THE LONDON STEREOSCOPIC COMPANY.

GENTLEMEN,

Having carefully examined the Fourteen Essays on the Stereoscope, which you transmitted to me, in competition for the Prize of Twenty Guineas, I have awarded this Prize to Mr. William Lonie, Mathematical Master in the Madras College, St. Andrews; and the Second Prize, which you subsequently authorized me to award, to the Rev. Robert Graham, Minister of Abernyte, in Perthshire,—the authors of the two Essays which gave the most correct account of the laws of Binocular Vision and of the theory of the Stereoscope.

Some of the other Essays had very considerable merit, but were more or less defective in their explanation of the laws of Vision, and of the bearing of these laws on the theory of the Instrument.

I am, Gentlemen, yours most truly,

D. BREWSTER.

*St. Leonard's College, St. Andrews,
January 5th, 1856.*

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THE STEREOSCOPE.

INTRODUCTION.

THE progress of recent discovery in the more occult branches of science has, without a doubt, been fully abreast of that large onward and homefelt movement wherein the present age rejoices, in all those more trodden and lucrative paths pertaining to agriculture, manufactures, and commerce,—and their's is sufficiently manifest and marvellous. With that true dignity likewise, which becomes the relation of head to hands, the former have been as decidedly in advance of their own more immediately dependent arts.

General Introduction.

Nowhere, we believe, has this progress been more remarkable than in those departments, called the science of the imponderables—of light, heat, electro-magnetism, and chemical affinity; though material expositions of industry must necessarily fail to a degree, in *their* exhibition. Their expression, moreover, through media of more symbolic language and diagrams, as puzzling to the unlearned as Egyptian or Assyrian hieroglyphics,—means in themselves too, at the best, by so much the more imperfect for simple instruction than models and substances, as they are farther removed from nature and art,—has long and strongly sealed those deeper fountains of intelligence from popular knowledge. But

Drawbacks upon the diffusion of Science.

they spring and bounteously o'erflow, nevertheless, on the mountain-tops, all unchilled by the lack of a larger social incense and reaction, which inaccessible libraries, as much as the want of leisure and education on the part of the people, have hitherto conspired to withhold from them. Happily for this and future generations, these restraints are not merely recognised and encountered by the learned themselves; they are already matter of keen feeling among the people, and of clear perception, careful consideration, and remedial anxiety among all legislatures, from the burghal and academic up to the highest in the nations. Our daily and weekly press—typical and pictorial—with cheapened and widened diffusion, are now manfully charging at the barriers of ignorance; while they too are girding and gathering to meet the wants of a growing intelligence in other principles than those of politic, civic, and domestic philosophy, and already emit occasional, sometimes continued feelers for such happy demand,—thus partially creating it, and all hopefully stimulating, while they herald the dawn of a larger area of scientific acquirements and better founded civilization.

Benefits of
later Science.

It has long been a frequent and reasonable complaint of practical men, that science and her votaries stand aloof from art and industry, and shroud their researches in mysterious technicalities only intelligible after a lengthened course of initiatory study; while they boast, in disparagement of the grapes, that the most beneficial discoveries have ever resulted from their own order, acting, though with a less intelligence, under the keener stimulus of commercial enterprize. For this, however, the difficulties and whole character of pioneering, enhanced, it may be, by high scholastic tendencies, are more to blame than any suppositions of class-feeling, or even insuperable difficulties of apprehension. And,

for half a century at least, the fault, if fault there be, has been largely atoned for, by an increasing series of popular expositions from the pens of the most eminent men of science and learning. Nor is the boast, more than the blame, any longer attachable: for, in the sciences we have specified, the most useful and beautiful applications to art, industry, and commerce, have originated with, and sometimes also been perfected by, the most illustrious votaries of science. It is thus, for example, that we owe the primary principle of the steam-engine to the philosophic experiments of James Watt in the science of heat,—to the science of electromagnetism we owe the transcendent utility of the telegraph—and to the cultivators of optics, even more directly, the valuable discoveries of polarization and of all those instruments whose simple application to the eye brings the near and remote within the range of clearest inspection and vivid relief. The camera obscura has, more recently too, opened up new flood-gates of light, knowledge, and beauty,—whilst, later still, the Stereoscope, the subject of our essay, originating in the observations of Galen, Leonardo da Vinci, Baptista Porta, Aguilonius, and others, and perfected by the ingenuity of Wheatstone and Brewster, claims from all the civilized world another tribute of gratitude to science, such as no social rank or wealth may fully repay.

SECTION I.

DISCOVERIES OF PROFESSOR WHEATSTONE AND SIR
D. BREWSTER.

THE name of *Stereoscope*, from the Greek στερεος a solid, and σκοπεῖν to see, is sufficiently suggestive of its

Reflecting
Stereoscope.

purpose, as an instrument for the creation of solid images, arising, by its power, from the plane pictures of any object or landscape, previously taken from two points of sight, and corresponding with the retinal pictures taken from nature by our two eyes. It was originally applied by Professor Wheatstone of London, to an apparatus of simple construction, but cumbrous dimensions, which, by means of two mirrors set at right angles to each other, enables the observer to conjoin the vision of the two dissimilar pictures, or rather of their reflected images. For this purpose, the pictures are placed in nearly parallel upright frames, and the mirrors, also upright, midway between them; the plane of the observer's eyes and vision being horizontal (only with slight variations according to the depth of the pictures employed), and his nose in contact with the common section of the specula. A right and left handed screw, also, situate just over and along the lower frame or standard, is adapted to give equable motions to these upright frames from or towards the centre, and thereby to increase or diminish the virtual images. The accompanying diagram (fig. 1) represents any horizontal plan of the instrument, or more properly, its perpendicular projection upon the lower frame, and will suffice for its further description in the more improved condition it has since assumed for experimental purposes by regarding the broken lines as arms attached to the bottoms of the upright frames, and moveable horizontally as well as equably beneath the mirrors, and around a common central joint.

Lenticular
Stereoscope
and Sir D.
Brewster's
Discoveries.

This contrivance, however unwieldy for popular service, and it certainly is so, even with all the appliances it has now received by hinges and sections, to box itself into a portable size, is yet admirably suited for such experimental research as it is now resigned to. And

we have been all the rather brief in its description, as it is now commercially superseded by another instrument of extreme simplicity and beauty, the invention of Sir David Brewster, and named by him the *Lenticular Stereoscope* from the lenses, whose novel application by halves and quarters he has so successfully employed in its construction, and subsequently extended to the formation of *Photographic Cameras*,—therein also most happily and thoroughly providing for the necessities of the Stereoscope. The physiological principles of vision for this and every other form of the instrument are precisely the same, and were also clearly demonstrated by this distinguished philosopher at periods both remote and concurrent with his numerous developments of these forms. His later application of these ocular principles to the solution of their distinctive *theory* is complete and all unquestioned since the date of its publication, and occurred very shortly after Mr. Wheatstone had (about eighteen years ago), with confessed inability of explanation, recalled the Royal Society's attention to the striking and valuable *relieving* power of binocular vision which we seek to describe.

SECTION II.

ON THE EYE, AND LAWS OF VISION.

The explanation of this theory will now occupy a large share of our attention; and, though its full comprehension is by no means essential to the use and enjoyment of an instrument—we especially refer to its lenticular form—which, by reason of its low price and exquisite value, is rapidly becoming a household companion, it is yet a most important part of the discovery,

General Introduction to
Laws of
Vision.

and very charming from its plainness and plenitude. It will, however, necessitate a short preliminary detail of almost every law of monocular vision, including, along with that pertaining to *distinct vision*, the no less important principles of *visible direction, position, and magnitude*, and fitly commencing, as we judge, with the construction of the *human eye*, itself a harp of thousand strings, and choral hymn in honour of the Deity, such as science alone may sound to adore.

Description
of Human
Eye.

The human eye, then, perhaps the most intricate, as it is certainly the most delicate outward organ of our frame, is very nearly spherical, only protruding somewhat further in front, for the very obvious purpose of commanding refractively a larger field of view. It is divided into two unequal segments by the plane of the *iris* or coloured membrane, so distinctive of its own varieties in the human family, and characteristic in some measure of the nations of the earth. The iris, again, is largely capable of contraction and expansion according to distance of view, and less promptly because less naturally, at pleasure also,—thus diminishing and enlarging the amount of light and pupillary hole whereby the light passes in. Between the iris and the *cornea*, which forms the protruding surface, lies the *aqueous humour*; and immediately behind this and the pupil, a small double convex lens, of unequal convexity and density, termed the *crystalline*: while the whole posterior chamber is filled with the *vitreous humour*, which is again bounded successively by the *retina* and dark *choroid* coating upon which the images are received, and from whence the ever-varying impressions of light, shade, and colour are conveyed to the brain through the optic nerve,—the aggregate of the retinal expansion. Regarding this retina attentively, a very small circular aperture is observable in its centre, called the *foramen*

centrale, assuming, from its superior transparency, the appearance of a further opening, though only indicative of an increased sensibility of the choroid, necessary, it is believed, for that distinctness of vision, which its impressions alone are found to convey. The *sclerotic coat*, of which the cornea may be regarded as the frontal continuation, incloses the whole, and has externally attached to it those muscles of motion whereby the most valuable results of distinct vision are so smoothly and effectively secured,

In this description, brief, but with the help of the annexed diagram (fig. 2) sufficiently characteristic for such primary knowledge as our subject demands, the student of optics will further recognise the perfected form of an artificial instrument,—the *Camera obscura*,—which has been long known as a fertile source of amusement, as well as artistic utility, and which has more recently, in connection with chemical discoveries, created another fine art in advance of common pictorial delineations, with a boundless field of application, a proportionate range of social and domestic pleasures, and richest promise of moral as well as taste ameliorations. Photography, indeed, is already a household word, and the Stereoscope an essential companion towards the full development of its numberless gratifications: but the recognition of the eye, as the *prototype*, in its very widest sense, of the camera, is probably neither so general nor so much valued as it appears to deserve. A short discursion, therefore, to illustrate this position, may at the same time aptly serve to clarify our previous description of the eye, and promote the acquaintance of an instrument now indispensably requisite for stereoscopy.

Camera
Obscura.

The most perfected camera of photography then (see fig. 3), in common use, has two lenses in its aperture for

The Eye and
the Camera
Obscura.

converging the rays upon the paper, glass, or metallic plate in the back of its chamber; and this is more thoroughly accomplished in the eye by the corneatic, not to mention the vitreous humour also, and the crystalline lens. In the latter, accordingly, we have by nature two invaluable properties of vision, which have never yet found their congeners in art,—viz., first, that of gradual and curvilinear refraction, caused by inequality in the lenticular medium, which increases in density from surfaces to centre, and secondly, the property of focal adaptation for different distances by reason of its supposed changes of shape or displacement. The iris too, with its functions for modifying the quantity of intromittent light, is but imperfectly represented by the occasional use of diaphragms, and appliances for quaquaversus or uniform light, with unruled temporal submissions of the sensitive material to its action. The choroid, on the other hand, considered in the light of modern optical science as the picture-receptacle of the eye (the retina being only the nervous vehicle thereof), has its counterpart certainly in that artificial sensorium, whose requirements of permanent instead of fleeting impressions apparently admit of no other parallel feature than simple obscurity in the box of art with accessories of dark coloured screens for backgrounds, such as we find everywhere in use. The retina were even more inimitable to human art, but there is happily no necessity for such an attempt to imitate this, or any of those exquisite nervous refinements which more confinedly minister to our mental perceptions: but the ocular concavity, most palpably useful in nature for the focal convergence of every larger field of view, is yet altogether ignored in photography (though not in the camera for drawing and exhibition), from inadequate manufacture in aid. These comparisons we cannot

doubt, and their justness, are abundantly known to science, it may be also to numerous artists in this delightful field; and, however imperfect, or even fanciful at present, will not fail with time and more accurate knowledge of the eye, to stimulate the needful reflection, conception, and experiment towards such measured correction of the cameral imperfections they expose, as mere human art may hope to attain in humble imitation of the Omniscient Creator's.

The law of *distinct and less distinct vision*, as an essential exponent of binocular as well as monocular vision, falls next to be considered, and is entirely unparalleled in its wonderful organism for economy, effect, and beauty by any artificial contrivance whatever. No one will need to be informed here, that a single and attentive glance of his eye at once secures the perception of a very considerable field of view, though the inadvertence of familiarity, combining with the fulness of nature's compensation may have withheld his observation of its deficiencies in distinctness and vividness; and also, that his contracted attention to a point or more limited view as invariably obscures his clear vision of all *before, beyond, and around*. Nor are these phenomena, when he does recognise them, entirely owing, as we would at first be apt to suppose, to the unity of mind and mental perception. In both of the cases, indeed,—for we recognise two in the remarks,—the indistinctness evidently increases with distance from the point of immediate attention. But they admit, nevertheless, of different and simple explanations. In the latter, wherein a plane, erroneously called by ancient theorists, with more especial reference to two eyes, the *horopter* of vision, may be considered as bounding the view, this effect of the oblique pencils appears wholly to arise from the unequal sensibility of the retina;

Law of Distinct Vision.

whilst, on the other hand, the dioptric necessity of focal accommodation for different distances, however little we feel its organic action, will indisputably prove the reason of that indistinctness consequent upon distance *before or beyond* the point of view, and finds its remedy entirely in those lenticular changes already mentioned, thereby altering the focus for every distance, and converging the radiant pencils of the objects upon the retina. Nature, however, has never neglected her children or her objects, nor has she the less failed to provide for the former also, the most ample compensation. And this, as ready experiment will show, consists in ocular motion. The eye, for this end, it will be seen, directs its axis to every point in succession towards which there is will for distinct apprehension, and thus culling, collects from every quarter the required amount of knowledge with the most admirable celerity and accuracy, and yet, with such smooth and tranquil movements as almost baffles our very consciousness. The necessity, as well as the rapidity of these motions, irrespective of consciousness, are very clearly discernible when we look closely at the eye of another who is engaged in quick reading. As indications of character, they are familiar to all; and are, doubtless, as capable of useful training as any other voluntary motions of the body whatever. The eagle eye, the sharp, the mild, the steady, and numberless other varieties of this sense, are all but modifications of rapidity in ocular concentrations and recoveries, and take their origin in the universal necessity of directing the images of all outward objects upon the inner extremity of the optical axis for distinctness of vision. It is in this necessity, therefore, that we recognise the principal law of distinct vision, and in the foraminial opening there existent the organism of its operation. And the fact, that the whole retina is ever picture-full,

will, nevertheless, be seen to fulfil a most wise and gracious design in the ocular economy—inasmuch as it insures both continuity of objective perception and large general effects, and therewith also, that provision against danger, such as otherwise would have been constantly incident to a limitation of vision through the foramen.

These ocular adaptations—lenticular and muscular—are so striking that they could not have well failed to attract an early attention, and they have accordingly been long known. The precise and important bearings they have, in connection with optical convergence, upon binocular and stereoscopic vision, was the later discovery of Sir David Brewster. The other general principles of all vision still remain to be adduced in the laws of *visible direction, position, and magnitude*; and *they* have acquired an additional interest here on account of a theory of retinal expansion and contraction, which had, with high authority, been attempted to be built upon or rather in despite of them, in explanation of the apparent anomalies of the Stereoscope.

Sir D. Brewster's Researches.

These laws also have been experimentally demonstrated by Sir David Brewster, and after some conflicting testimony consequent upon the imperfect data of other investigators, may now be assumed as accepted and true expositions of ocular optics. With that of distinct vision, they have little in common, though essentially concurrent with that of indistinct vision from oblique pencils, and, both physically and metaphysically, are of the highest importance. The compound direction of light through the eye, as preliminary to the law of visible direction, may be thus simply enunciated. Every point of an object, to which the eye is directed within a field of at least 60° inclination to its axis, emits a ray or rather cone of light to the eye, which, with the exception of axial rays, after one refraction at the external

Law of Visible Direction.

surface of the cornea, suffers another of a more complicated nature in passing through the crystalline lens; and, finally, crossing the optic axis at a point in or a little behind that lens, impresses forthwith its degree of light and colour upon a point of the choroid and retina, which, with reference to that axis, may be called the converse of the radiating point. The crossing point we have mentioned is necessarily but slightly different for different rays; but the axial rays of each cone, exactly as in the case of a single lens (see fig. 12) are with good evidence believed to cross at the same point, immediately posterior to the crystalline, in the common centre of the cornea and choroid. This invariable point, called the *centre* of visible direction, assumes its position behind rather than in the middle of the crystalline, in conformity with the law of single lenses—the whole eye being thereto regarded as one lens, and the inner lens only as subservient to the position of the principal focus upon the choroid, instead of behind it. These axial rays, it has also been found, alone determine the visible direction of their respective points of radiance, and this admits of rigid experimental proof by simply cutting off any amount of the conal radiation. The complicated refraction of the crystalline is due not merely to the unequal convexity of *its* anterior and posterior surfaces—greatest in the latter—but more especially to the unequal density of its substance. The effect of the unequal convexity of that lens in shortening the focal distance to suit the magnitude of the eye is accordant with the law of sines in optics, and well understood; but the inequality in the medium itself, operating as it must in curving the directions of the passing rays, is little adverted to. Dr. Thomas Young has ascribed it solely to the necessity of gradual refraction; so that, while equally powerful with a more dense

and uniform medium, it further obviates the abruptness of common lenticular refraction, and avoids such reflections at both surfaces as would otherwise have inevitably interfered with and impaired the refractive vision. It is not improbable to suppose, however, that, by reason of its inner density, it acts another part also, in aid of our most distinct vision. Be that as it may, the ultimate issue of ocular refraction is, that the radial line of axial incidence upon the retinal sensorium,—that is, through the vitreous humour,—is so nearly, if not perfectly coincident with the original direction through air, for all obliquities to the optic axis within at least 30° , that the visual and real directions of every point within that compass may be held as one and the same.

The *visible position* of objects is more readily explicable; with the single eye it would at first appear to be entirely dependant upon the fore-mentioned principles of focal accommodation for distance and visible direction. That these alone are far from affording a just and sufficient knowledge of distance, however, a glance at any aerial or seaward object, gives instant proof. The sportsman will tell how capable of improvement is the judgment formed from this adapting power; but no education, he will find, can ever avail to ensure its sufficiency for our daily wants. How then, it will be asked, is it that we judge so accurately with one eye? Simply by comparisons with intervening and proximate matter, such as is never wanting, except in the case of the heavenly bodies, and in the use of such instruments as the telescope and microscope, which, in common with almost all optical instruments whatever, rather find their several advantages in the concealment of true position. With two eyes on the other hand, all these means, so important for the very safety of those who experience the loss of an eye, are amplified, if not

Law of Visible Position.

entirely superseded by convergence of the optical axes, the invariable accompaniment of our every visual perception of neighbouring objects.

Law of Visible Magnitude and Solidity.

The *visible magnitude and solidity* of bodies, again, as perceived by the single eye, is but a corollary, in some measure, from the position of points, qualified in the one case by *retinal magnitude*, and in the other by *shading*. The relation of these magnitudes is neatly expressed by the formula $V:v::R.D:r.d.$ signifying that the visible magnitudes are proportional to the compounded ratios of the retinal magnitudes and distances. Though of long standing and very clear demonstration, this law has been sometimes disputed, and its correctness has been lately again impugned upon the authority of certain remarkable phenomena of the reflecting Stereoscope, which have neither, it appears to us, been studied with due regard to the crossing of the optic axes, nor to the obliquity and consequent diminution of the picture images. These shades, on the other hand,—which must not be confounded with shadows,—therein appear to have a larger utility for supplying the want of optical convergence; and are, consequently, in all their infinite varieties—coloured as well as uncoloured—the subject, *par excellence*, of the most assiduous study to the painter, the art-representative of monocular vision. Even art, however, can only be said to imitate them as yet, without geometrical understanding: for they are also a subject of the most refined geometry. And a striking proof of their value to the single eye, though none the less apparent to both, may be found in the phenomena of any picture, best observable in a large drawing of considerable buildings, when the point of sight is far apart from the one proper to its perspective. Now, all shades are properly defined to be the diminished

light consequent upon obliquity, enhanced by the unequal diminution which arises from unequal distances of the points of lines and lines of surfaces. And, in the pictures we have instanced, another and different shading will be superimposed upon the originals proportionate to the change of view-point, its own, and its comparative size. In the case of a single building or range of buildings, this point may be sometimes assumed so as to increase the relief in the most vivid degree; and supplies, we think, a juster explanation of a remark made by Mr. Wheatstone in his first stereoscopic paper, regarding the increased appearance of solidity in a picture-building, whose perspective has been delineated upon an oblique plane.

SECTION III.

ON BINOCULAR VISION.

These considerations—thus condensed to a degree so little available for flowing description—may never the less approve themselves from the simplicity they are calculated to impart to the theory of binocular vision,—now the more immediate course of our theme.

Introductory
to Binocular
Vision

Regarding natural solidities then, the first and most striking consideration is, that by means of two eyes and their retinal pictures, we have yet only perception of one object. If these pictures were perfectly equal, little farther explanation would be needed towards a full and easy apprehension of the cause. The anatomical proof of optic nervous decussation—from the brain to either eye—and the other supposition which this has long served to support, that the retinæ are also of like correspondence in fibrous points—as accepted

Ancient
Theory.

and expounded by Sir Isaac Newton and many others, would settle the whole matter in the most satisfactory manner. And this again would receive strong confirmation from the binocular circle and sphere of the Germans passing through the centres of our two eyes, and successively through the whole of every object we view. It has been long known, however, that these pictures, excepting for distant matter, are essentially and sometimes very widely dissimilar for proximate objects. The apparent insignificance of these dissimilarities only, we must conclude, had failed to arrest a prior examination, and deferred the discovery, both of their cause and application, till a period, when, with happy conjuncture, photographic and other arts, such as those of Baxter and Paul Pretsch were ripe and ripening for its service. These very dissimilarities have thus given birth to a new art, which not only sheds lustre upon an age, remarkable for discoveries and useful applications, but may be said, in a fashion, to have doubled and intensified it.

Binocular
Vision of
a Point.

When we look at any single point with both eyes, our perception is single, not merely because that point has impressed its pictures on the centres of each eye, but rather because the mind itself has, all unwittingly indeed, but not less certainly, compared its monocular results; and finding by them, and more perfectly still, by the convergence of our optical axes, its visible position alike, has pronounced it one and the same. These monocular results, properly speaking, are only efficient in ascertaining the direction; for focal adjustment, as already remarked, is little available for short distances, and in the case of disjoined points, other means of comparison are consequently absent. But the remedy is no less providently than abundantly supplied by our instant consciousness of that optical convergence, which, like the effects of a base in trigonometrical mensurations

at once affords a most accurate means of distance judgment; and again demands of us and of all, in its full appreciation, warmest tribute of thanks to the glorious intelligence of our Maker,—another glance, indeed, behind the veil of His government of original providence and unwearied love.

In this most simple case of all, a single glance is amply sufficient to ensure correct judgment, so rapid is mental perception. With similar rapidity and exactness we form our judgments when the point is extended into a circle of considerable size. When the object has a third dimension in space, however, the circumstances have entirely altered. Even in the case of the circle, distinct vision can only be accomplished by successive motions of the eyes—always in unison—to bring the points of the retinal pictures over the foramina; and this will hold much more in the latter: for not only will the two axes have to be converged over a plane, but other convergencies will now necessitate a corresponding series of focal adjustments to suit every depth and relief of the figure. In general, such is the extreme mobility of the eye, that this is all done without the smallest abruptness, and with so marvellous a celerity, that we are altogether unconscious of the motion. The focal adaptations, moreover, are so thoroughly natural and unstrained,—following the axis of either eye with the most invariable grace and attachment,—that even whilst we gather of the harvest of information, alike from the near and remote, which they yield, we are all but unconscious recipients of their bounty.

It is quite true, notwithstanding, that these necessities for distinct vision are as invariably accompanied by momentary but unheeded indistinctnesses of every other point of the object unimpressed upon the foramina: but this is common to single as well as to double

of a Circle,
and of three
Dimensions.

Indistinct-
ness of Single
and Double
Vision.

vision, and proves in the former a most valuable means for our every judgment of distance and solidity. Not only so, but in this very process of point-vision of relief with two eyes, we do actually see, when the attention is turned to it, double pictures of every other point, line, and surface, beyond that on which the two axes are converged. These double pictures are, however, naturally withheld from the mind's eye, so to speak, by the very act of point attention and the rapidity of our every objective regard. And still the necessity for such convergence is paramount,—bearing ever in its train the most delightful clearness of knowledge, enhanced for every convergency by a perfected judgment of point-position, and consequent solidity.

Diagramatic
Illustration.

The lower part of the diagram (fig. 10.)—which as a whole has been calculated to serve another and ulterior purpose also—is designed to complete the apprehension of these results of increased relief and vividness which accompany the enjoyment of binocular vision. The general solid is there represented by a cutting or frustum of the well-known cone, whose facial sections have so wonderfully proved the exponent of the heavenly motions and other phenomena of universal nature. The axial lines of convergency are only exhibited in the illustration for *four* points, being the lateral extremities of the base and top diameters, parallel to the visual base; but these are obviously all that are required to designate the character of the solid, and will equally subserve the full explanation which every pair of radial delineations from the solid would render of our double and distinct vision of it, by imagining the ocular continuity of these pairs of lines over the intervening lines and surfaces. Nor can it prove more difficult, we conceive, to carry any imagination, for similar intelligence, over the more complex realities which lie in profusion

within every reach, and therewith to comprehend in all its generality, that law of binocular vision, which equally suffices to explain the natural perception of solidity, and the general theory of every Stereoscope.

This law of optical convergence by points is so close and peremptory a sequence of the law of distinct vision, that we had even previously taken its apprehension for granted. In describing the reflecting Stereoscope we have also implied the reader's acknowledgment of dissimilar pictures as a consequence of double vision, and yet the means of single perceptions. The proof of this proposition, by one or two illustrations, forms our next topic, and the proposition itself may be thus enunciated with mathematical accuracy. *All natural objects whatever, of one, two, or three dimensions, especially of the latter, necessarily imprint dissimilar pictures upon the retinae of our two eyes: the appearances which these pictures give may be represented on planes, by the arts of common and photogenic perspective; from whence the natural appearances may be reproduced by means of the Stereoscope and other devices.*

Proposition
of Dissimi-
larity.

Examples of these dissimilarities, upon which the Stereoscope depends for its sustenance, will be found in figures 7, 8, 9. The broken lines which we have depicted upon the base of the conic frustum (fig. 10) are also meant to represent the same dissimilarity in conjunction with the visible position and magnitude. The same pictures on a larger scale than that of visible magnitude (on the scale of plane pictures which are meant to be seen and united by crossing the optical axes) are more clearly exhibited in the upper part of the diagram. But the whole of these series of pictures must necessarily differ, it is evident, from the retinal impressions, both in size and also from their representation on planes instead of concavities, while correctly

Illustration
of Dissimi-
larities.

displaying, nevertheless, their respective dissimilarities. Such specimens of the more simple solids, are, besides, best fitted to exhibit the *linear* inequalities, and to aid the conception of *their* nature and increase for every nearer objective distance. Let us now see whether these consequences—of ocular convergence, as well as picture dissemblance—will be in anywise altered with an instance of greater complexity—say that of a statue or the human face itself. The simplicity of features (see fig. 5) which distinguished the conic frustum, now gives place, it is true—not certainly to a less, or less beautiful symmetry, but to a vast variety of reliefs, depressions, and contours, remarkable amid all their variations, for the exquisite grace of unnamed and unnumbered curves, the pride and the charm of God-like humanity. But these are no less, in whole and in part, dissimilarly depicted upon our eyes, and give distinctness, moreover, in the very same manner, from the different degrees of convergency or axial inclination which their every prominent or retreating feature constrains. The cheek will thus be seen to exact a greater convergency than the ear—the forehead and the chin will demand another advance and angular enlargement upon that of the cheek, while the nose, beyond the whole countenance, will claim, as befits, the greatest convergency of all. Nor will the eyes of the observer in the least degree fail to meet these requirements. They will, on the contrary, range not only over these, but through every feature of the entire countenance, with similar unison—with a speed rapid as the lightning, and altogether as marvellous in the contrasting benefits of knowledge, beauty, and delight, they are in every respect so admirably designed to confer. The differences of the retinal projections will be equally apparent for this case and for all, when we

consider the attendant and invariable consequences of every plane perspective from different points of view. These consequences will likewise be developed here; and if our position be taken directly in front of the countenance, they will show themselves, not only by right and left-sided pictures of the whole, but by rights and lefts also of every central feature, and by differences in all, corresponding to their prominence and obliquity.

The illustration of these diversities, it is plain, might be extended to any degree. They are, in fact, the subjects of our every nearer regard, and minister to all our ocular enjoyments. The extent of the inequalities will vary, it is no less evident, with every size and distance of the object till the axes verge into parallelism in the far remote—only finding their limits in the unchangeable length of the visual base—the distance of our eyes from each other. A curious and singular conclusion, however, is directly deducible from these phenomena, which, though somewhat out of our way, is otherwise so deserving of notice, that we shall offer no excuse for adducing it here by a single illustration. It consists in the fact that monocular vision is really in some respects superior to the binocular. For the purpose of this demonstration, we will assume that a sphere or globe is the object of our binocular attention. Each retina will then be impressed with a circular image, of equal area, but of unequal shadings and pictorial contents; and occupying, when the eyes are directed to the nearest point of the sphere, nearly similar positions on either retina. A ten-inch terrestrial globe affords an excellent means of examining the results, when the eyes are placed in its equatorial plane, and at the distance of its diameter. Thus viewed, it is geometrically demonstrable that we shall see with each eye precisely one-third of the surface of the globe;

Superiorities
of Monocular
over Binocu-
lar Vision.

and that this will include for each eye 120° of the equatorial line, and twelve of the lunar spaces of 10° made by the meridians which intersect it. Eleven only of these spaces, however, will be visible to both eyes in common; but as each eye must have one more to make up its complement, these will consequently lie on opposite sides the globe. And while, therefore, this globe will appear to any single eye to contain only twelve lunes and their corresponding mapping, thirteen of them will be actually visible to both eyes—eleven of them being doubly seen, and the two extremes of single and separate illumination. The single eye has thus the advantage over both eyes in the greater uniformity of its light, and also in the avoidance of their flickering duplicities; though it will be readily understood that our judgment of the spheres in either case is really very little influenced by the extreme lunes—so foreshortened from obliquity as to be almost imperceptible. In figure 7, wherein these pictures and their respective lunes or crescents are represented, the perspectives are so far incorrect as they do not mark this foreshortening. Geometrical pyramids will be found to exhibit similar inequalities even in a more striking degree; and find their adaptation for such exhibitions in the convergency of their own sides to a summit. The square, hexagonal, and like pyramids, for example, may all be so placed in relation to the eyes, that whilst with one we may view the whole of their triangular surfaces, we shall yet, with the other, only discern the half of them. And, in consequence, no fewer than three highly dissimilar appearances of any such solid may be almost simultaneously realized by simply and successively shutting each eye, and thereafter regarding them with both eyes open.

SECTION IV.

THEORY OF THE STEREOSCOPE.

THE complete theory of these phenomena with its bearings upon that of binocular vision will be found in the Transactions of the Royal Society of Edinburgh for the year 1844, clearly and eloquently detailed by Sir David Brewster. The disparities which our illustrations abundantly evidence, when so drawn, and considered in the light of their natural origin, were necessarily the precursors of the whole art which involves the manufacture of the Stereoscope and of its suitable pairs of pictures. The re-combination of these disparities, however, had led Dr. Whewell and Mr. Wheatstone to suppose, by way of explanation, that our eyes were really capable of *uniting any unequal lines*—at least of such unequal lines as were not disproportionate to those of perspective according to oblique vision—and *that* at once and entirely, rather than by the law of points and distinct vision. This were, it appears by that paper, utterly to overthrow the principle of visible direction; for although we may doubtless perceive an indistinct union of the two lines, yet Sir David has experimentally proved that the entire, distinct, and simultaneous coincidence of such inequalities is impossible. The more general proof which he has also therein given for the same purpose, is founded upon the law of visible direction which we have previously explained, and proceeds somewhat in this manner:—When two unequal lines (and the same reasoning holds good for surfaces) are brought into stereoscopic union, they do necessarily and certainly

Wheatstone's
and
Whewell's
explanation
of Binocular
Vision.

impress unequal pictures on the retinae of our eyes. It hence follows that each pair of radiations from the extremities of these lines will pass respectively through the two centres of *visible direction*, and must, consequently in the equal eyes give unequal central angles to indicate the retinal magnitudes. But, before the lines can coalesce to the appearance, these angles must, in conformity with the law of *visible magnitude*, become perfectly equal, for the lines are at equal distances from either eye; and this again were to presume, in direct violation of the former law, that the ocular centres were capable of shifting their positions respectively before and behind their more proper and permanent places. Such a fluctuation of these centres, however, is altogether inadmissible into the science of the eye; and the theory which requires either this hypothesis or that of retinal contractions is in consequence entirely superseded now by that law of point-perception and optical convergence, which we have just adduced in explanation of all natural vision of solidities, and which, in a very few other sentences, will also enable us to explain the full reason of the conjunction of all dissimilar stereoscopic drawings into their appearances of relapse and relief.

For this purpose we shall again make use of figure 10, and premise that the plane, on which the conic figures are there delineated, is to be viewed in perspective, as standing at right angles with that of the paper—a shadow being added to facilitate the conception. When the eyes therein are respectively directed, by crossing their axes, to any two corresponding points of the bases of the pictures, the resulting vision is evidently that of a single point at the intersection; and it is no less evident, that, for every other such pair of basal points, there is little or no change of the axial convergence. But when, in succession, a pair of the summit-points become

the points of view, the picture-dissimilarity instantly comes into play, and necessitates a larger axial angle and nearer convergence. The vertex of this larger angle, seeing that the mutual distance of the eyes remains unaltered, must, therefore, have approached still nearer to the observer, and therewith for that point, must have imparted to him the appearance of relief. Now, this increased angle is evidently due to the greater distance of the corresponding points of the top circle pictures, and the single relief which arises from any one pair of them were itself enough, with so simple a solid, to effect the appearance of entire relief also. But this alone would still be inadequate to the full explanation of our vision of the complete solid. The character of the eyes themselves, in accommodation for distinct vision, must be taken into consideration; otherwise we must believe that the oblique sides of the solid, which we perceive, acquire their unity to the mental perception by means of unequal retinal impressions; and this again would demand a belief either in shifting centres of visible direction or in retinal elasticity, such as we have just seen to be without the shadow of any foundation whatever. The eyes, therefore, it is almost certain, cannot have this power; but they have another in that of rapid ocular motion, which herein, just as in the binocular vision of natural solids, acts as a full compensation; while it also at the same time insures a more distinct vision than might have been consistent with any other equal simplicity of organism. Even the necessary motions of our eyes, moreover, in roaming over very considerable fields of view for clear vision, are very small in space, and their origin in muscular appliances for speed rather than power are by no means unparalleled in comparative anatomy. Of this, the third eye-lids of birds and the haw of the horse are well-

known examples. Even the digital speed of a smart penman, or the rapidity of manual motion by the action of the brachial muscle might be cited to the parallel. But, irrespective of extraneous proof, these motions are distinctly perceptible in the eyes of a rapid reader, and therein of all, afford the most ready illustration of the whole process, whereby, in dissimilar pictures and natural solids alike, we visually skim from point to point, converging the optic axes as we proceed, and gather, almost instantaneously, those resultant ideas of shape, solidity, colour, and other relations, which we everywhere experience.

SECTION V.

INSTRUMENTAL DESCRIPTIONS.

Description
of the Stereo-
scope.

FROM these considerations of optical science and the general theory of the Stereoscope, we are now prepared to pass, in due order, to more simple descriptions of the art and instrument themselves. Of all the various contrivances, which have been devised by the illustrious *savans* we have so frequently named, for effecting the combination of the plane dissimilar pictures, the *Lenticular Stereoscope* commends itself by a very marked superiority of simplicity and effect. This instrument has accordingly proved by far the most, if not the only one, acceptable to the public. It (fig. 4) is now very simply, as well as elegantly constructed of a box, nearly in the shape of a rectangular pyramidal frustum, with two eye-pieces, or short tubes, about $2\frac{1}{2}$ inches apart, and agreeable with the ordinary distance of our eyes. A side slit, or narrow opening, just over its

base, is adapted to permit the successive introduction of plate or paper containing the pictures, and a flap-door in one of the broader sides to admit in the most equable manner the light required for their illumination. Lenses of the most perfect equality are inserted into the eye-pieces, and are the only portions, distinctively characteristic of this instrument, which, from their all-importance, require a more detailed explanation. They are, in fact, no longer lenses in the usual acceptance of the word, but either halves or quarters of one full lens, and are so placed that the thin edges or arcs of each are turned inwards, towards the other, somewhat in the case of the semi-lenses, like two capital D's, one thus, and the other in reverse Γ . or $D-\Gamma$. In either case, moreover, the new lenses, after being cut from the original, are rounded off to fit the eye-tubes; though that, of course, is merely done in deference to the natural shape and elegance of these tubes, rather than for any purpose of utility beyond that of the more fragmentary segments. These lenses, thus cut and prepared, will now be seen to secure two invaluable effects—precisely such as are required for an improved binocular vision—in the first place by assisting the eyes to combine or superimpose the picture-images they create; and in the second, by magnifying them without the necessity of recurrence to a larger or less portable box. Thus superimposed, these virtual images or pictures will then appear to coalesce, and midway between the real pictures, to reproduce the originals of one, two, or three dimensions from whence they were taken. The magnifying power, here as elsewhere, depends upon the convexity of the lenses, while the displacement, and ocular convergency which follows it, is due to what is called the refracting angle at that point of the lens where either eye is applied.

Rules for its
Construction.

It forms a proper and principal part of the business of the artisan to select the full lenses in modification of his instruments to various degrees of displacing and magnifying power. The explanation of their optical principles lies within *our* present province. Before proceeding to this explanation, however, which is only such as the student of optical science—familiar with its fundamental laws—may have already forestalled, it seems proper that we should here refer the former to the rule of his workmanship which must direct the due appliances for picture displacement. And, for that purpose, we shall adopt the rule and expression of it, which has been given by the inventor himself. “In order that the two images may coalesce”—it is Sir David Brewster who speaks—“without any effort or strain on the part of the eye, it is necessary that the distance of similar parts of the two drawings be equal to twice the separation produced by the prism or lens. For this purpose, measure the distance at which the semi-lenses give the most distinct view of the drawings; and, having ascertained, by using one eye, the amount of the refraction produced at that distance, or the quantity by which the images of one of the drawings is displaced, place the drawings so that the average distance in similar parts in each is equal to twice that quantity. If this is not correctly done, the eye of the observer will correct the error by making the images coalesce, without being sensible that it is making any such effort. When the dissimilar drawings are thus united, the solid will appear standing, as it were, in relief between the two plane representations of it.” (see fig. 15.)

“In looking through the Stereoscope the observer may probably be perplexed by the vision of *only the two dissimilar drawings*. No sooner do the refracted

images emerge from their respective drawings, than the eyes, in virtue of this tendency, force them back into union; and though this is done by the convergency of the optic axes to a point nearer the eye than the drawings, yet the observer is scarcely conscious of the muscular exertion by which this is effected. This effect, when it does occur, may be counteracted by drawing back the eyes from the lenses, and shutting them before they again view the drawings. It exists chiefly with short-sighted persons, for whom the Stereoscope may be constructed with concave semi-lenses, or quarters of lenses, still with their thin edges next the other; and, when there are only *two* drawings, it may be prevented by a partition, which hides the right-hand drawing from the left eye, and the left-hand drawing from the right eye."

These rules and remarks are so precise that they might even dispense with further comment from us. It is proper to mention, however, that the partition to which they latterly refer, was, in truth, a part of the original instrument; though its use is now generally dispensed with, for the sake of another advantage of very pleasing and startling effect upon the beholder. The nature of this advantage will be afterwards more fully detailed. Meanwhile, it is sufficient to say, that it consists in the power, which this instrument in its lenticular form alone retains, of creating, by means of three pictures—two similar and one dissimilar—both the alto and corresponding *ri-relievo* of every natural object, at one and the same instant. And though, as will be hereafter seen, these singular appearances can only be realized in the absence of the partition; yet the utility of the latter, even then, is most perfectly met by the more recent improvements of placing the semi-lenses at sufficient distances from the lower ends of their

Use of Partition, &c.

tubes, or in inner tubes for vertical motion, and so as effectually to cut off the radiations of the left picture from the right lens, and those of the right picture from the left lens.

Optical Laws
of Semi-
lenses.

Passing again to the optical laws, which are involved in the use of semi-lenses,—we had just mentioned that the degree of displacement is entirely due to the size of the refracting angle,—the density of the substance or sine of its refraction being the same. The particular nature of this law of sines need not occupy our attention here, as the lenses of which we speak are the same as those employed in almost all optical instruments whatever, and made of the usual material—glass. The special effect of a refracting angle, however, necessarily involves the general nature of refraction; and this, as is well known, consists in breaking or changing the primary direction of all luminous rays passing from one medium into another of different density. This change of direction, again, is always uniform for the same two substances, and is nearer or more remote from a perpendicular line at the common surface, according as the ray passes from the less to the more dense medium, and conversely. When, therefore, a ray of light passes through a prism, such as we have drawn in figure 11, it suffers two deflections for every case excepting those when it happens to fall at right angles to either of its two surfaces. When the ray is primarily incident at an obtuse angle with the converging part of a line or surface, both of these refractions, it will be seen, tend towards the same side of the lens, and that is, invariably *away* from the prismatic angle. When, on the other hand, it comes from the other side of the perpendicular, a certain counteraction of the first refraction occurs at the second surface: but this has no connection with our use of the

semi-lens; because, in every case, the radiations from the stereoscopic pictures will come from the first-mentioned side: and even were it not so, the displacing result is unaffected. Our illustration exhibits the refractions rather too large for the glass lens; but the deductions are unaltered, and the effect is again represented in figures 12, 13, and 14.

It is not the least of the peculiar and large advantages derivable from semi-lenses, that their displacing power is not only almost unbounded in extent, by reason of the varieties of the full lenses, but that each also within itself should contain a very considerable range of the same power. This will at once appear, we believe, from the few pairs of tangents we have drawn in fig. 13, as representatives of the prismatic inclinations of that semi-lens at these points; and, in the recognition of this range, will equally justify their new designation and use in the Stereoscope, as *variable prisms, with magnifying power*.

Semi-lens a
Variable
Prism.

The nature of this magnifying influence is scarcely so easy of explanation: though *its* fact is matter of common experiment in reading-glasses and single microscopes. It is, moreover, entirely different from the magnifying power of lenses by focal images, and very limited in extent for the Stereoscope, on account of the general size of the pictures; though microscopic Stereoscopes,—perhaps the very best, as they are certainly the most elegant variety of the lenticular—again obviate this deficiency to an almost unlimited extent. In treating of the laws of distinct vision, we have already said that distinctness was effected by points for all nearer objects, and by very limited circular fields for larger distances, proportionate to the focal adjustments of the eye. When the object is nearer than six or seven inches, however, it is well known that we do not see even

Magnifying
Power.

points distinctly. The object, when slightly within that distance, becomes gradually more and more blurred in appearance, and when very near, altogether indistinct. Now this, and the focal adjustments alike, are owing to the ocular requirements of parallel or nearly parallel rays, for the best vision,—such rays alone being most perfectly converged into foci by all lenses. And if, consequently, we can, by any contrivance, make the rays which proceed from an object, however near, enter the eye, either parallel or nearly so, we shall necessarily see it distinctly. This, again, being the reverse of the process of the crystalline, may be effected by any artificial lens whatever;—from whose focus, it is demonstrable that all divergent rays will, on permeating the lens, emerge in parallel rays. And if we, therefore, place any object in the focus of a lens held close to the eye (or even a little apart), and having a small focal distance, the rays will enter the eye parallel, and we shall see the object very distinctly, as it will be magnified in the proportion of its present short distance from the eye to the distance of seven or eight inches, at which we see small objects most distinctly. But this short distance is equal to the focal length of the lens, so that the magnifying power will be equal to seven inches divided by that focal length; and the object will have its distinctness increased according to the degree of parallelism which the lenticular texture or focal accuracy may be fitted to secure.

Application
of Optical
Laws.

The application of these remarks to the lenticular Stereoscope must now be sufficiently obvious. Its box, being generally made about five inches deep, the lenses employed in its construction will necessarily be also of that focal length, and the magnifying power nearly double. This power is the same for all portions of the same lens; but the prismatic angle varies by increasing

or decreasing the distance of the ocular point of application from the margin, where it is greatest of all. By giving a motion to the semi-lenses of the instrument equally towards or from each other, the amount of picture displacement may therefore be considerably varied, while the magnifying power remains unchanged. Such a motion, indeed, would become absolutely necessary should the Stereoscope be hereafter adapted for the reception of pairs of pictures differing considerably in size; and this increase may be met even for very large pictures by using a thicker lens, unchanged in curvature or focal length, but capable of giving more displacement by reason of increased tangential angles at the margin. In these circumstances, however, it might be desirable to preserve the common tubular size; and this could only be done by grinding down the semi-lenses or quadrants on their thick sides, or by cutting any similar segments less than the semi-lenses from the original, and rounding them off as before. For purposes of experiment or amusement rather than utility, the lenses are generally placed at a little depth in the tubes, and a limited motion given to the tubes *to or from* the drawings, to vary the magnitude of the apparent solid; and in the microscopic form of the instrument this is very advisable for the sake of effect.

The series of diagrams from fig. 11 to 15 inclusive are designed to illustrate these descriptions, and might, indeed, with a little reflection, themselves suggest the whole instrumental exposition. We have already explained the objects of figures 11 and 13. Figure 12 exhibits the nature of the focal divergence into parallel rays from right to left, and *vicê versâ*, the operation of the ocular lens also, in focalising the parallel rays into a perfect retinal picture. If the pupil of the eye were equal to the full sized lens, the same illustration would

Diagrams for
Optical Laws.

completely evidence the nature of the radiations which issue from a semi or quarter-lens into either eye in the act of picture deflection and enlargement. But this, along with the enlargement, is more correctly represented in figure 14, and again, along with the actual union in figure 15. In the latter diagram, it is true, the apparent coalescence of the picture-images into a solid is given without the magnifying effect, for, in the usual-sized pictures of the Stereoscope, the solid image apparently occupies or obscures a part of each picture, and is incapable of perspective delineation; but that effect again is most thoroughly realised by the use of the instrument itself.

To complete the apprehension of the truly exquisite value of this instrument in its various fittings and economy, it is first necessary to add, that the box itself is only useful in so far as it excludes all side lights from the pictures, and permits a more uniform illumination of them,—as from one quarter only—through the flap-door. It was originally made in the simple form of a pair of spectacles, with or without the addition of a rod at right angles to the visual base, and a panelled frame, fixed or moveable on the rod, for the reception of the drawings. But its most characteristic appliance in every shape, consisted in halving the lenses and in thereby securing an almost perfect uniformity of convexness and density, exactly suited to the natural equality of our eyes.

Refracting
Stereoscope.

Nor will these advantages lose from a closer inspection. It is now clear, we trust, that not only one, but two distinct principles operate in the use of the lenticular Stereoscope,—comprising first, that for displacement of the picture images, arising from the refractive angle of the lenses at the points of ocular application, and secondly, that for their enlargement by reason of lens convexity. The former of these principles, it

will also be obvious, might be partially satisfied by the use of a pair of thin triangular prisms, such as might be cut for the sake of uniformity from any longer one, though still wanting the special utilities of a variable refraction peculiar to the lenticular virtual prism; and the latter by placing lenses of selected equality over them: and this arrangement was accordingly afterwards proposed and recommended by the learned Professor of King's College, with the name of the *refracting*, in conformity with his original appellation of the *reflecting* Stereoscope. It is simply, therefore, an alteration upon the lenticular adaptation, without the least material change, only disjoining the single appliance of the other, for double effects; and greatly inferior, because more difficult of correct manufacture. It is difficult at all times, indeed, and in any shape, to execute two equal pieces of workmanship,—and these difficulties are certainly no less experienced in the construction of equally dense, homogeneous, and unstriated glasses, as well as in their sections for prisms, and in the spherical, not to mention conal attritions of lenses—respectively the arts of the glass-maker and lapidary—successive operations, it will be observed, of the most refined delicacy and appliances. These drawbacks upon the manufacture of the refracting Stereoscope, are, however, almost entirely obviated by the use of the semi and quarter lenses; which, on the other hand, after careful selection of the full and double-sized lens, immediately avail by the simple bisection and quartering to supply both equality of glass and of superficial form; and further conjoin, as we have just proved, the simultaneous advantages of equal enlargement and equally varying displacements.

We must now content ourselves with a very brief reference to the variety of other inventions, which have

Other Instruments.

been devised and published, to subserve the pictorial use of binocular vision. They are severally represented in the series of diagrams from 11 to 22 inclusive. Their full comprehension requires a mere elementary knowledge of catoptrics and dioptrics; and they vary very much in proportion to their application of these principles. The only one of them which presents a marked peculiarity, and has found a suitable appliance for popular use is represented in figs. 21 and 22, cased and uncased. It is styled the Total-reflection-Stereoscope, from its property of creating, by reflexion, a reverse image of any single symmetrical figure, and by refractive compelling its ocular coalescence with the real picture, as seen by the other and naked eye. The character of this reflection by means of a common prism, or basal section of a prism, such as is easily procurable from any good piece of plate glass, is displayed in fig. 22. It will give the appearance of a hollow or raised cone,—see the diagram,—respectively from the drawing when so placed, and when turned half round. Its prism may be exchanged for a section of a deeply-convex lens with polished end; and when the other half of the same lens is applied to the right eye, a magnified solid may be seen likewise. By using a reflecting prism for each eye, the Total-reflexion Stereoscope is rendered into a pseudoscope, or instrument for converting natural solidities into corresponding concavities, and concavities into solidities. The principles of the inverting telescope and common mirrors have also been employed in the construction of other instruments for a similar purpose: but, though sometimes productive of very amusing and interesting illusions, their phenomena are too unreal and capricious for popular favour. Two dissimilar pictures are requisite for all the other instruments we have depicted.

In fig. 16, the displacement of the left picture, which must be previously set very near to the right one, is effected by a very thin or shallow prism. It is scarcely achromatic, but this slight imperfection may be obviated by using a drop of water instead, between two pieces of thin glass, fixed at a small inclination from each other. Fig. 17, again, is not properly a new instrument. It is a doubling of the former, to enable the observer rapidly to pass from the appearance of the raised to that of the corresponding hollow figure. These have received from their author, Sir David Brewster, the names of the Single and Double prismatic Stereoscopes. The next three, emanating, in common with these and the Total-reflexion Stereoscopes, from the same master of optical science, are reflecting instruments of the most simple construction and character. Their respective names of Single and Double reflecting Stereoscopes, taken along with the delineations of the figures, will tell the full tale of their nature and use. And the last two of them may be made to realize to the observer, in common with the Lenticular Stereoscope (but much less readily), the vision of the converse solids at the same instant; though neither these nor the prismatic have yet, so far as we know, come into the market.

SECTION VI.

OF UNAIDED BINOCULAR VISION.

FROM these considerations, it will now readily appear that the ultimate and chief value of every Stereoscope must lie in their respective capabilities of extracting, so to speak, one or more images from the dissimilar pictures, and superimposing them correctly one upon

Chief Value
of all Instru-
ments.

the other. Their comparative value, on the other hand, must be rated according to the many other qualities we have detailed. But there is yet another mode of effecting these *unions*, by means of the naked eyes themselves, which is deserving of a very serious notice. This consists in a compulsory convergence of the optic axes towards positions before and behind the picture planes, to effect the same coalitions, and is only practicable by a certain straining and drilling of the eyes, which, however unlikely to be habitually exercised, might, in such event, cause both squinting and pseudoscopy in the presence of all recurring patterns of nature and art.

Compulsory
Convergence
of Eyes.

Sir David Brewster has investigated the effects of this compulsory convergence of the eyes with a view to the union of similar as well as dissimilar pictures, and elicited many striking and useful results. Figure 6 is meant to illustrate the nature of this constraint, both towards a point anterior and posterior to the planes. The habitual tendency of our eyes to converge their axes upon the plane of the real objects or pictures is somewhat difficult to overcome at once, more especially when we desire to unite them in front; but they may be assisted in the effort by various contrivances, according to the position of the pictures we observe. And, among the many singular effects which we can thereby realise, both from equal and unequal figures, nothing is more remarkable than the tendency or desire as it were, of the eyes, to unite and fix the two pictures hovering before them; to alter their plane, and, when dissimilar, to convert them into some figure of three dimensions,—sometimes in relief, sometimes in the converse, sometimes in both at the same time; and the suddenness with which the images change their distance and start into union, giving birth to a new plane of

pictures or solid figures on which the optic axes are converged, and release the eyes from that unnatural condition in which they had previously been placed.

The art common to all the contrivances for assisting this mode of binocular vision, the Stereoscope included, consists in obscuring one of the pictures from the one eye, while it is at the same time fully visible to the other. Crossing tubes, convergent tubes, diaphragms of any kind with single holes in them, plates of thin glass with single wafers on them, and steady interventions of pin-heads or the like, are all specimens of such ways and means as are best calculated to render the assistance: and those who acquire by such aids the power of uniting dissimilar figures, will not, in any case of mere experiment, it is plain, require the use of a Stereoscope, unless for enlargement of the pictures, or for thorough exclusion of the side lights. When, however, there is only one figure, recourse must likewise be had to the appropriate instrument, the Total-reflexion-Stereoscope, which is as yet, the only one at all adapted for the purpose, and limited, besides, to the relief of symmetrical solids.

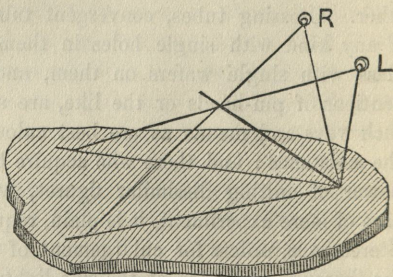
Means of assisting it.

The employment of strained eyes has, moreover, given rise to a new and essentially distinct branch of binocular vision. Already, it has opened up to the observer two classes of phenomena, such as none of our instruments apply to. The first of these is comprised in the strained combination of two meeting lines, like the legs of a pair of compasses, when the eyes are placed at different heights above their plane and at different distances from the angular point. Viewed from any one position, these lines will unite by crossing the optic axes, and rise from the paper or plane while appearing to rest on it at the angular point. This binocular line will then be seen to enlarge or diminish

Binocular Vision of Meeting Lines.

with every motion of the head *from or towards that point*, and with simultaneous movements, like the spoke of a wheel may be made to pass over a considerable circular arc. If the head itself be moved *in a semi-circle*, whereof the point of the lines is the centre, the same simultaneity of movements again appear, and more extensively. The full diagrammatic explanation of

these remarkable phenomena is somewhat complex; but may be lineally continued by any careful draftsman from the figure we annex; though



in making the experiment itself, it must never be forgotten that there will occasionally be another duplicity visible, in consequence of our distinct vision by points rather than by lines or surfaces, and here all the more liable to occur on account of the strained and unnatural use of our eyes. They form, nevertheless, a very instructive as well as amusing exhibition, and solve in the most satisfactory manner, that singular phenomenon of double compasses and ruler, which has been noticed and largely commented on by philosophers long prior to the discovery of the true theory of binocular vision. The whole subject, as well as those of the subsequent phenomena we proceed to relate, will be found minutely detailed by the investigator himself in Vol. XV. of the Transactions of the Royal Society of Edinburgh; but it is in the second class we have referred to, that we must still look for the more valuable results of useful application.

This class is, indeed, of the very broadest extent, and is itself divisible into two branches. It includes all those phenomena wherein it is desired to unite a great number of equal and equidistant pictures, such as, on the one hand, the recurring patterns of carpets, paper-hangings, plaidings, and the like; and, on the other, of cane-bottomed chairs, trellis work, windows with small square or lozenge-shaped panes, and, generally, all combinations of alternating equalities and transparencies. Perhaps the most interesting of them all is the appearance of a papered wall, when covered with a variety of many-coloured figures, recurrent with the most formal precision and regularity. "These figures," we again quote the language of Sir David Brewster, "being always at equal distances from one another, and almost perfectly equal and similar, the coalescence of any pair of them, effected by directing the optic axes to a point between the paper-hanging and the eye, is accompanied by the coalescence of every other pair. If we, therefore, look at a papered wall, without pictures, or doors, or windows, at the distance of *three* feet, and unite two of the figures—flowers, for example—at the distance of twelve inches from each other, the whole wall will appear covered with flowers as before; but, as each flower is composed of two flowers, united at the point of convergence of the optical axes, *the whole papered wall with all its flowers* (in place of being seen, as in ordinary vision, at the distance of *three* feet) *is seen suspended in the air at the distance of six inches from the observer*. At first, the observer does not decide upon the distance of the suspended wall from himself. It generally advances from the wall to its new position, and, when it has taken its place, it has a very singular character. The surface of it seems slightly curved; it has a silvery

transparent aspect; it is more beautiful than the real paper, and it moves with the slightest motion of the head. If the observer, who is now *three* feet from the wall, retires farther from it, the suspended wall of flowers will follow him, moving farther and farther from the real wall, and also, but very slightly, farther and farther from the observer. When the observer stands still, and the picture is suspended before him, he may stretch out his hand, and place it on the other side of the picture or wall, and even hold a candle on the other side of it, so as to satisfy himself that the suspended papered wall stands between his hand and himself."

Uses of fore-
going.

In all these and like phenomena, some remarkable discrepancies occasionally occur, which, when well understood, lead directly to several useful consequences. Irregularities in the arts of paper-hanging and upholstery of carpets, imperfections of geometrical drawings with recurrent parts, and of like designs for the arts and manufactures, are thus instantly detected from the differences of relief and traced to their origin. Already, they have proved useful in explaining some illusions incident to deranged vision, such as may have more frequently occurred after indulgence in stimulants, and in the languor of muscular relaxation of the eyes after severe illness.

Binocular
Vision of
Transparenc-
ies.

The consequences of the compulsory convergence and union of pictures *behind* their plane, which is also more easily effected, are scarcely less wonderful. In the case of papered walls and the like, the opacity of the actual surfaces necessarily prevents this species of convergence. It is, however, very readily accomplished, with most delightful manifestations, in the observation and union of cane-chairs, venetian blinds, zinc-perforated screens, and many others such as we have previously detailed.

The experimenter may even, in such instances, commence with a distant field of convergence, and, gradually drawing it towards him by simple approach to the real plane, may continue to attract the illusory field in front thereof by again retiring; therein exemplifying the successive and continuous effects of both distant and nearer optical convergence. In these experiments, it is, of course, essential that the transparent recurrences be nearer each other than the distance of our eyes; but, in all circumstances, the observer will find the illusion so perfect, that neither touch, measurement, nor any other actual demonstration, will convince him of its true character. He may, actually, if he chooses, feel what he does not see and see what he does not feel; but nothing will in any degree, shake the infallible evidence of his sight as to the position of the new plane whereon he is gazing.

Nor is the compulsory action—it can be scarcely called either a use or abuse—of the naked ocular sense confined to the vision of such phenomena. If we turn again, for a little, to the consideration of single solidities and their pictures, a totally different species of ocular straining and control will present to us another series of illusions of more frequent but quite as remarkable occurrence.

We have hitherto referred to objects of three dimensions, chiefly as solid bodies. The phrase, however, is also inclusive of concave bodies, and, in that relation, involves another branch of binocular vision, which has deservedly received a large concurrent share of attention and development. This branch comprises the whole subject of converse figures, such as cameos and corresponding intaglios, statues and their masks, medallions and their matrices, castings and their moulds, and might, with propriety, have been considered under the laws of monocular vision, upon which its phenomena

Conversion of
Relief by
naked Eyes.

almost entirely depend. The occasional and very capricious conversions of bas-relief plane pictures into the corresponding depressions by the naked eyes, must have been frequently seen in all times. They are common to vision with either one or two eyes, but are more readily apparent to the former. They are very often noticed by geometers to arise from their plane drawings of solidities, such as those of the complete crystals and many other kinds of solids, and are then entirely dependent, we believe, upon the principle of indistinct vision in planes. A greater diversity of opinion, however, exists regarding the causes of the fluctuations of more complex pictures, such as of cameos and intaglios. By some philosophers these fluctuations are believed to be a consequence of single vision alone, and to arise from the monocular deficiencies for distance-judgment, more especially in the want of binocular optical convergence. The phenomena, however, are apparent to two eyes as well as one, and are probably more accountable by the simple considerations of shadow and shade-effects. And the latter view of their origin has now obtained strong confirmation from some experiments made by Dr. Gmelin of Wurtemberg, and more conclusively still, by Sir David Brewster, upon reliefs attainable to the appearance merely by the use and constraint of one or two eyes, from masks of the human face and other natural and artificial concavities. "In one of these, the clustered columns of a Gothic pillar sunk into hollow fluting, and in another a field of wheat, viewed through an erecting telescope when illuminated by the setting sun, exhibited the strange appearance of having been trenched, and of the wheat growing in the trenches, as well as upon the elevated beds between them." And thus also, it is recorded that Lady Georgiana Wolff had, on an occasion of

glaring sunshine, observed in an Egyptian desert, "that all the footprints and other marks indented in sand, had the appearance of being raised out of it." The latter appearance, indeed, must have been pretty frequently seen under any similar circumstances, and has also, we believe, been sometimes observed on the western sands of St. Andrew's. The dimples apparently visible in hammered agate and mother of pearl, the apparent hollows at the polished knots of mahogany tables, and conversely the imperfections of alabaster or partially transparent marble busts, are other examples all of a like delusion, entirely arising from shaded representation on the one hand and actual shades on the other.

SECTION VII.

INSTRUMENTAL CONVERSION OF RELIEF AND ADVANTAGES OF LENTICULAR STEREOSCOPE.

THE pseudoscope is the instrument, as we have before stated, which has been devised by Professor Wheatstone to realise (somewhat imperfectly indeed) from nature and at will these singular, and sometimes highly ludicrous, phenomena of conversion. And, in connection herewith, we come now to notice more particularly the perfect conversions which are obtainable by means of pictures, from all the Stereoscopes, either by exchanging the relative positions of the pair, when there are two, or in the case of the Total-reflexion-Stereoscope, by turning the single picture half-round. The truncated square pyramids (delineated in fig. 8) will readily subserve our remarks. If then, we converge these, respectively right and left eyed pictures of a single pyramid, with the eyes alone, to a nearer point

Conversion of
Relief by
Instruments.

than their plane, the result, it is known, will be a *solid pyramidal frustum*, because the distances of the corresponding points of the smaller squares are uniformly greater than those of the larger squares, and when the axes are crossing each other, the greater distance must geometrically cause the greater axial angle and consequent relief. But if, on the other hand, these distances being less than the visual base, the pictures are thrown back into coalescence, we shall have the appearance of *its converse* in the shape of a *hollow frustum*, and that simply because the greater distance of corresponding points must now geometrically cause the smaller axial angle and consequent depression.

Position of
United Solid,
&c.

From these, again, the Stereoscopes only differ in the operation,—not in the results,—by lifting the picture-images, so that one of their faces shall actually coincide; and, when the instrument is well constructed, this union takes place in the plane of the pictures. In all those instruments, represented by figs. 16 to 20, the necessity for this union in the plane is absolute, on account of one of the pictures being seen by the naked eye, unless, indeed, the strong ocular tendency to unite the images at every stage of displacement comes into play. But, in the others, there is no such necessity. On the contrary, the coalescence in the *lenticular* and *reflecting* Stereoscopes is entirely that of images, not of drawn pictures, and they consequently allow, by their adaptations for motion, the combination either before or behind the plane as well as in it. They alone, therefore, can properly admit of pictures of various degrees of dissimilarity; and these pictures (generally daguerreotypes) are previously photographed *for the former*, side by side, on the same plate and of suitable sizes, and so placed in the instrument that the right and left pictures shall meet the right and left eyes respectively of the observer

(see fig. 5); whereas, *for the latter*, the pictures must be separate and always difficult to adjust, and the order likewise reversed to admit of a similar position of the right and left mirrored images, which, even then, from the very nature of mirrors, must only produce reverse reliefs or depressions.

There are several other advantages peculiar to the lenticular Stereoscope, which our limits alone forbid us to bring forward. We will just mention, however, that it has the most excellent facilities for viewing and relieving those glass transparencies which are now so much and so justly admired. And, before finishing our instrumental description, we deem this also a fitting place to notice the beautiful illustrations which it supplies of our modifications of size-judgments of any object by reason of differences in the apparent distance.

Other advantages of Lenticular Stereoscope.

These modifications are only less common in ordinary vision, because of our general accuracy of distance-judgment; but they nevertheless do naturally exist for distant objects in many circumstances, and have been long recognised as the source of our perception of an *elliptical* heavenly vault, by reason of the differences in quantity of the interposed air and the consequent differences of blue tinting with which painters in aerial perspective are most familiar and most sorely perplexed. The lenticular Stereoscope has been successfully employed by its author to effect similar delusions of our distance-judgment as the air does in nature, and therein to exemplify most perfectly the familiar differences we observe in the magnitude of the horizontal, the midway, and the culminating moon. This is done by inserting *three* pictures of a conic frustum into the Stereoscope, the two outer being alike and the middle a dissimilar but symmetrical top-view of the real conic frustum. In this way the solid

and hollow cone are realised at the same time, and the different apparent distances of the summit circles will give different apparent magnitudes precisely as with the horizontal and culminating moon; while the summit circle of the middle picture itself will illustrate the midway size of the same luminary.

SECTION VIII.

MEANS OF PICTURE SUPPLY.

Dissimilar
Pictures by
Drawing and
Geometry.

HAVING thus concluded our exposition of the laws and phenomena of binocular vision in all the generality and detail of which we have deemed our limits susceptible, we shall now hasten to finish the more descriptive portion of the Essay, with a brief account of the means at the command of existent art for creating a supply of suitable pairs of pictures. At first, this supply was almost entirely confined to dissimilar drawings of geometrical solids. These were delineated without much difficulty, from points of perspective equally distant on either side of the required common axial point of view, and the degree of relief was necessarily proportionate to that distance. This practice was consequently in perfect unison with our perceptions of increased relief when approaching like actual solidities. But, for the production of drawings, with all the precise dissimilarities which the Stereoscope imperatively requires, something more than common accuracy of drawing from mere sight was needful. And, hereto, geometry was called to aid—not in vain. A most simple and accurate rule for securing the projected perspectives was at once derived from the

properties of similar triangles, when once the visual base ($2\frac{1}{2}$ inches) the distance of the pictorial plane (D), and of the actual solid (d), both reckoned on the common axis of the eyes, were determined. The distances of each projected point of the solid from the common centre, or common axial intersection of the picture plane

(δ) is then expressed by the formula $\delta = \frac{5 D - d}{4 d}$.

This formula is by no means difficult of application; and when symmetrical pictures of a symmetrical solid are required, the use of the rule may be abridged by first completing one entire projection—the right or left at will—and thereafter copying its reverse or reflection, by turning it over face to face upon the same or a different sheet, and pricking its points and corners for after completion.

The same expression may likewise be transposed to give the apparent distance of papered walls, cane chairs, and the like, when their visible position is altered by compulsory convergence. Thus, when Δ signifies half the distance between any two recurrent patterns,

Formula for
Pictured
Wall.

we shall have the required distance $d = \frac{5 D}{4 \Delta + 1}$

and D alone will, in this case, be variable for all convergencies.

In order to understand now, the more valuable, equally accurate, and unboundedly extensive means of procuring dissimilar pictures from the *photographic camera*, whether by the daguerreotype or talbotype process, it is of much consequence to bear in mind the mutual relations subsisting between the magnitudes of of the pictures and that of their objects or fields of view. That instrument, it is well known, is now equally applicable to the attainment of large and small

Pictures of
Photography.

object pictures, though in the case of large figures, and more particularly of landscapes, there are still great difficulties to be surmounted by reason of the permanence of the chemical focus for all distances, such as, in the eye itself, are most perfectly overcome by the organism for focal accommodation. In the case of small and near objects, sufficiently dissimilar pictures may always be got by a *single binocular camera* with semi or quarter lenses placed at eye distances from each other in corresponding eye tubes; and when one oblong paper or plate is used, this device has the further advantage of securing them with an equalised preparation, and at the same instant of time. These pictures, when viewed through the Stereoscope, will accordingly exhibit a relief precisely proportionate to that of the object when viewed at the cameral distance. But when pictures of large buildings, distant prospects, colossal statues, and the like, are required to be seen in the relief of binocular vision, a different course must be pursued. The retinal impressions of our own eyes are no longer sufficiently dissimilar to give such relief to the natural vision, and we, consequently, lose their warrant for expecting it by the pictures obtained through cameral eyes of the same base. Could the objects, indeed, be reduced by scale and compasses to a suitable degree the objection would no longer hold. This, however, except for plans of buildings and such like perhaps, is scarcely possible, and, happily moreover, it is all unneeded; for the semi-lenses are not necessarily confined to one camera: they are, on the other hand, as readily fitted into two as one, still retaining, too, the equality of power and focus belonging to all bisected lenses; and even the plates or papers, which must now be dissevered, may yet, by a perfectly simultaneous series of preparations, acquire a large, if not entire community in their degrees of sensi-

bility. Thus prepared, the photographer has only to remove his cameras to any distance within the breadth of his object, or, more properly, either without or within that breadth with due regard to natural effect, that he may secure all the advantages of reduction and alike of dissimilarity. The distance he takes will, of course, in every case, determine the relief of the binocular solid, but that distance and relief may be over as well as underdone : it must always be taken for the best effect, in subservience also to the size or depth of the Stereoscope. These relations, when duly observed, will make the optical and cameral convergencies the same, or nearly so ; and this convergency, when alike, becomes subject for calculation from the formula $\text{tang. } \frac{1}{2} A = \frac{d}{2 D}$,

when d represents, in the one case, the usual distance of the eyes, and in the other, the distance of cameral removal, and D the respective distances of the natural and cameral eyes from their apparent solidities.

SECTION IX.

PRESENT AND PROSPECTIVE VALUE OF STEREOSCOPE.

ON reviewing the large variety of matter which we have here attempted to conduce towards the exposition of binocular optics and its appliances in art, we can scarcely hope, however earnest our desires, to have thoroughly succeeded, within compass so limited, in bringing the subject to the level of every reader. Our sources of information in the learned, yet easily understood, papers of Sir David Brewster and Mr.

Wheatstone, will be found in the Transactions of the Royal Societies of Edinburgh and London, and will fully repay the most lengthened perusal. These remarks would, however, lose much of their point and importance, did we now forego the more pleasant duty of laying before the reader the present and prospective value of the Stereoscope in fields far more flowery and attractive than its science.

Though a discovery but of yesterday, in a sense, it is yet already the prolific means of most charming enjoyments to thousands—increasing to its instrument-holders with every additional plate and pair of pictures they can procure—naturalizing their portraitures and picture-groupings,—their landscapes and designs—their pictures of statuary, of architecture, of natural history, and vertu; and in the art of photography, its invaluable handmaid, all rampant through museums and sculpture-galleries—among the grand and beautiful of both ancient and modern architecture—among men, society, and nations—through all cities and all scenery. The riches of our own Crystal Palace are even now being executed in befitting transparencies for their Stereoscopic enjoyment over the land. And the advertisements of commerce already announce to us the import of binocular views of most exquisite finish and numberless varieties from Paris and Vienna,—Rome and Naples,—Athens, Venice, and Pompeii—from Egyptian monuments of long-faded science and power—and from Swiss-Alpine scenery of more picturesque, and hoary grandeur.

Nor are its benefits confined to those of mere amusement. It has found a home in the studio of the painter, the atelier of the sculptor, the repertories of the naturalist, and the quiet retirement of the art-designer. From these it must ere long extend to the architect, the engineer, the mechanist, and the draftsman of more

useful arts. But, in the former, we have evidence that it has already taken root—already have its young and graceful leaves yielded grateful shade to the fancy of higher art; it has bloomed and borne fruit in the works of the chisel and the pencil. Nor are its capabilities for efficient assistance to the latter professions less important or promising. To the architect and civil engineer it may serve to furnish the most exquisite models of existing architecture and works of stability; to the mechanist those of all machinery; and to the designer of every art it will soon avail to accumulate similar modellings of all art-creations whatever, of taste and genius, of beauty and utility. To the student of every path it is capable of imparting knowledge; for there is no branch of knowledge whatever—metaphysics scarcely excepted, alike dependent with other sciences upon matter for its every parallel and expression—wherein so natural pictures may not throw illumination. But it is in the promotion of the highest science and art of all, of liberal and life-long education, that we must expect hereafter to witness its widest and mightiest effects upon the intellectual progress and moral amelioration of mankind.

A short consideration of *these* prospective advantages will, at the same time, serve to evince the benefits we may more immediately expect from its extension to the useful arts and industries of civilized nations. In what respect then and from what cause is it—to commence with the primal education of our schools and colleges—that the assiduity and zeal of youth first begin to show languor and distaste? From partial experience we can reply, *in* nothing but the abstractness of truths there conveyed, and *from* the universal deficiencies for objective illustration. Even the inherent beauty and large applicability of the truths of the higher sciences are too

often unequal to sustain *their* thirst for such attainments, in lieu of the more practical and natural erudition for which the intellects of all ages and classes are now eagerly striving. The best of school and college outfits, much more of private houses, are yet altogether inadequate to supply these craving demands. The cry is still for common things! And for these a more natural education and better founded instruction imperatively demand,—that the symbolic and ideal give yet further place to the pictorial and real—that spoken and written language alike yield more to that of sight and sense, and only rank hereafter as the secondary because the more artificial instruments of knowledge. Museums and apparatus alone, however, could most completely meet this demand; and these, with attached workshops and ever-present nature herself were, with proper youth-guidance, the best schools for instruction and mental development. And such museums, hitherto confined to our cities and crystal palaces, are unhappily still beyond provincial and remote acquisition. But in the resources of the Stereoscope and photography we may confidently look for a most worthy though partial substitute, with ever enlarging supplies—all vivid with an enhanced imitation of nature and art—and at prices infinitely more within every reach. We contemplate, indeed, a fast approaching period, when our school-books will be uniformly filled with double instead of single pictures, and our every class-room enriched with pairs of larger drawings for the more general and more vivid illustration of classics and mathematics, of geography and all natural sciences. For the former, Stereoscopic spectacles are already prepared, and for the latter also, it appears to us, that crossing tubes with swivel joints, and illuminated pairs of photographic transparencies, magnified upon screens

as with the magic lantern, were all that is required to exhibit their rotundity and solidity even to a hundred spectators. And even without this magnifying power, the simpler tubes might be exchanged for crossing telescopes, such as those of opera glasses, of shortened foci and small power, in whose intersections, when the erect images were united, the very same phenomena might, without chamber obscurity, be realised.

Our larger maps will then no longer appear in unseemly planes, but will arise to the stereoscoped eyes of the young geographer from the *perspective* plane projections to their proper convexity. And even the maps of smaller countries may have their very mountains and vallies, their cliffs and their banks, their every larger relief and depression according to nature herself. The student of geometry will no longer be mocked by the fluctuations or relieving failures of his solid representations, and the complexities of his trigonometrical and astronomical diagrams will for ever disappear. With what enhanced interest, too, will not the student of natural science survey from such sources, even in his lone, mind-lighted chamber, the Stereoscope-realised apparatus and larger diagrams of his class-room; and with how much greater ease and enticement will he not thereby comprehend the knowledge of principles they may be devised to convey. What numberless varieties, moreover, of other appliances besides his actual apparatus, will not the teacher be able to treasure up in portfolios instead of presses, and attainable at prices incalculably lower than the originals, yet wanting in nothing of their reality but the motions and utilities his learning and eloquence will therein find scope to describe. The intricate frameworks of all our manufactories—the ingenious contrivances of all arts and pertaining to all industries, will then and then only be suitably intro-

duced into the lecture-room. From all countries may the bridges and the engines—the monuments and the edifices—all local appliances and fixtures—be uplifted in their solidity, their beauty, and their fitnesses, and almost bodily transferred, for explanation within our colleges and for admiration within our homes. The very ships of the ocean with their every engine alike for peace or for war—their harbours and appurtenances—the fortifications of cities with their temples and palaces, their streets and their towers, their arches and domes, interiors as well as exteriors—will all combine to accumulate the tale of our clearer knowledge and redoubled enjoyments.

Nor will natural history less than physical science, experience its advantages; for plane pictures of every kind, of animate as well as inanimate nature, will give place to the more vivid and perfected images of rotundity, distance, and reality. The birds of the air, the fish of the sea, the animals of the land will all be brought forth from the dingy recesses of museums to our schools and our homes. Their specimens of minerals, crystals, and shells, of antiquities and curiosities, will no longer elude the search of their votaries in endless presses. Arrayed in pairs, and arranged in books and portfolios, they may be ever at hand to minister to our intellects, to increase our knowledge, and to exalt our devotion. Dried specimens of plants will give place or prove but secondary aids to the botanist. The florist and the arborist may yet find the flowers and trees of every clime transplanted in appearance to their own sweet gardens of home. The lakes and the mountains, the hills and the vallies, the icebergs and volcanoes—aye, and even the rivers and the cataracts,—the whole glory and grandeur of nature—may yet be collected by photography from every quarter of the globe, and

naturalized by stereoscopic agency to sweeten all our pleasures, to charm our societies, to educate our youth, and to shed the halo of more intellectual enjoyments around our domestic hearths.

If, from such hopes, rather than accomplishments (almost millennial in their promise), we again turn to the fine arts of painting and sculpture, we shall witness more realised conceptions of the value of the Stereoscope. Nor need we offer any excuse whatever, when, with a view to that testimony, we here transfer, in totô, its eloquent expression by a North British Reviewer, in an article* of the highest literary art and most complete rendering:—

“The art which we have now described,” says this Reviewer, “cannot fail to be regarded as of inestimable value to the sculptor, the painter, and the mechanist, whatever be the nature of his production, in three dimensions. Lay figures will no longer mock the eye of the painter. He may delineate at leisure, on his canvas, the forms of life and beauty, stereotyped by the solar ray, and reconverted into the substantial objects from which they were obtained—brilliant with the same lights, and chastened with the same shadows as the originals. The sculptor will work with similar advantages. Superficial figures will stand before him in three dimensions, and, while he summons into view the living realities from which they were taken, he may avail himself of the labours of all his predecessors, of Pericles as well as Canova; and he may virtually carry in his portfolio the mighty lions and bulls of Nineveh, the gigantic sphinxes of Egypt, the Apollos and Venuses

* The article was published in May, 1852, and will be found at page 187, Vol. XVII. of the North British Review. It is from the pen of Sir D. Brewster.

of Grecian art, and all the statuary and sculpture which adorn the galleries and museums of civilized nations.

“ The celebrated French painter, M. Delaroche, has pointed out the advantages which photography gives to his own art. He considers it as ‘ carrying to such perfection certain of the essential principles of art, that they must become subjects of study and observation, even to the most accomplished artist. The finish of inconceivable minuteness disturbs in no respect the repose of the masses, nor impairs in any manner the general effect. The correctness of the lines and the precision of the forms in the designs of M. Daguerre are as perfect as it is possible they can be, and yet, at the same time, we discover in them a broad and energetic manner, and a whole equally rich in tone as in effect. The painter will obtain by the process a quick method of making collections of studies which he could not otherwise procure without much time and labour, and in a style very far inferior, whatever in other respects might be his talents.’ If such, in the estimation of so competent a judge, be the advantages of photographic pictures on a plane surface, how great must be the benefit which stereoscopic photography confers upon the artist. Binocular daguerreotypes or talbotypes of the human face, taken under all the conditions of repose and of muscular action, and reconverted into the original solid, give a new power to the portrait and the historical painter. In place of drawing from the living object, whose different attitudes and positions he cannot, by any contrivance fix, till they are delineated, he will draw from innumerable forms, fixed, as if by death, and yet exhibiting the vigour and plumpness of life. Instead of trying to catch with his pencil those evanescent and ever-varying forms, which give beauty and expression to the living subject, but whose shades and shadows are

ever shifting, as the day advances, or as the clouds are dispersed, he may study the same forms under a fixed shadow which neither time nor circumstances can change. The plane pictures, indeed, which are thus combined into solid forms, may be supposed more suited for imitation than his own drawings from the solid; but this would be to copy merely the solar picture, and not to improve himself by appealing directly to the living subject. From the stereoscopic art, too, the historical painter would derive great advantage. Groups of living figures might be taken binocularly and reproduced for his study and imitation.

“But it is to the sculptor that the reproduction of statues from their binocular representations will be of most avail. In order to master the difficulties of his art, the sculptor must have before him, as studies, either casts or drawings of those great works of art which have immortalised their authors. The one he cannot procure and he must therefore travel to foreign lands or to distant parts of his own country to make drawings of these works of art. However great be his power of delineation, he will find it a difficult task to record those beautiful forms and expressions, on which their beauty depends. If the sun shines into the gallery where he works, even though its rays are not incident upon the statue, its shadows will not only correspond with numerous points of illumination, but will be varying every minute as the sun advances in the heavens, and as his rays fall upon objects in the apartment reflecting different quantities of light, and differently inclined to his own locality. Even in a day without sun, the shadows upon his statue will imperceptibly change, and with whatever accuracy he may draw its outline, he will find it impossible to transfer to his tablet those delicately convex and concave forms which can be appreciated and

measured only by the length and nature of their shadows. We hold it, therefore, to be impossible to copy a statue, which it requires a day or a considerable portion of time to finish,—we mean, of course, to take such a copy that the artist can use it in his studio to observe the nice details of the original, and to transfer them in their real or modified character to some analogous work of art in which he is engaged. In this predicament, the art of photography comes powerfully to his aid, and, at one instant of time, he may procure views of the statue in all its different aspects, and with all the shadows which variegate its surface; and by taking pictures in each aspect by means of the binocular camera, with the smallest possible aperture, he may take right and left eyed representations of it, which, when combined stereoscopically, will enable him to draw from this temporary statue, all the forms of its parts, with their fixed shadows, and thus to transfer to his own work the ideas which it is so well calculated to supply. We have already said, that a French sculptor has, upon such principles, and with such auxiliaries, actually modelled a statue. In taking busts and statues from the *living* subject the sculptor will derive pre-eminent advantages. Double pictures of the whole or of any portion of the subject may be taken and raised into relief, and from such pictures executed on one side of the globe, an artist on the other side may produce an admirable statue. The dying and the dead may thus be modelled without the rude contact of a mask, and those noble forms preserved, which affection or gratitude or patriotism has endeared.

“But if such are the advantages which this new auxiliary to art gives to the painter and the sculptor, how are we to estimate the boon which it confers on society, and on the domestic circle? We have endeavoured in another place to describe these advantages

solely in reference to monocular photogenic pictures which represent external scenery, and living objects upon a plane surface; but when we read this description under the conviction that the scenes and objects and persons which are named or referred to, may, or might have been reproduced from binocular photographs, and displayed to the eye in true retiring perspective, or in the relievo forms of life and beauty, it will appeal to the judgment and the affections in a deeper tone, and with a more powerful influence.

“How limited is our present knowledge of the architectural glories of other nations—of the ruined grandeur of former ages—of the gigantic ranges of the Himalaya and the Andes, and of the enchanting scenery of lakes, and rivers, and valleys, and cataracts, and volcanoes, which occur throughout the world. Excepting by the labours of some travelling artists, we know them only through the sketches of hurried visitors, tricked up with false and ridiculous additions which are equally mockeries of nature and of art. But when the photographer has prepared his truthful tablet, and ‘held his mirror up to nature’ she is taken captive in all her sublimity and beauty; and faithful images of her grandest, her loveliest, and her minutest features are presented to her most distant worshippers, and become the objects of a new and fascinating idolatry. The hallowed remains which faith has consecrated in the land of Palestine, the scene of our Saviour’s youth and pilgrimage and miracles—the endeared spots where he drew his first and his latest breath,—the hills and valleys of the holy city—the giant flanks of Horeb, and the awe-inspiring peaks of Mount Sinai will be displayed to the Christian’s eye in the deep lines of truth, and appeal to his heart with all the powerful associations of an immortal interest. With feelings more subdued will the antiquary and the archi-

tect study the fragments of Egyptian, Assyrian, Grecian, and Roman grandeur—the pyramids, the temples, the aqueducts, and the obelisks of former ages. Every stone, every inscription, will exhibit to them its outline and its story. The grey moss will lift its hoary frond, and the fading hieroglyphics will utter their faltering voice, and tell their mysterious tale. The fields of ancient and of modern warfare will unfold themselves to the soldier's eye in faithful perspective and unerring outline; while, in his fancy, reanimated squadrons will again form on the plains of Marathon and occupy the gorge of Thermopylæ.

“But it is not merely the rigid forms of art and of external nature, the mere outlines and subdivisions of space, that are thus fixed and recorded. The self-delineated landscape is seized at one epoch of time and is embalmed amid all the co-existing events of the social and physical world. If the sun shines, his rays throw their gilding over the scene. If the gentle shower descends, the earth and the trees glisten with its varnish. If the wind blows, we see in the partially obliterated foliage, the amount of its agitation. If the air is nearly at rest, the indistinctness of the aspen leaf measures the force of the zephyr's breath. The objects of still life, too, give animation to the scene. The streets display their stationary chariots, the esplanade its military array, and the market place its colloquial groups; while the fields and the woodlands are studded with the various forms and attitudes of life. In this manner are the incidents of time and the forms of space simultaneously recorded. Every picture becomes an authentic chapter in the history of the world, and the direction and the length of the shadow of the spire marks the season, while the shadow of the dial's gnomon points to the hour when nature has been caught in her charms.

“In considering the relations of photography to the art of portraiture, we are disposed to give it a still higher rank. Could we now see in photogenic light and shade, Demosthenes launching his thunder against Macedon, or Brutus at Pompey’s statue, bending over the bleeding Cæsar, or Paul preaching at Athens, or Him whom we must not name, in godlike attitude and celestial beauty, proclaiming good will to man—with what rapture would we gaze on impersonations so exciting and divine? The heroes and sages of ancient times, mortal though they were, would thus have been embalmed with more than Egyptian skill, and the forms of life and beauty, and the lineaments of glowing affections and intellectual power, the real incarnations of immortal man, would have replaced the hideous fragments of royal mortality scarcely saved from corruption.

“But even within the narrower, though not less hallowed, sphere of the affections, where the magic names of kindred and home are inscribed, what a thrilling interest do the realities of photography excite! In the transition forms of their offspring, which link infancy with manhood, the parent will observe the traces of his own mortality and in the successive phases which mark the sunset of life, the child in his turn will read the lesson that his pilgrimage too is destined to close.

“Nor are these delineations interesting only from their minute accuracy or their moral influence. They are instinct with associations at once vivid and endearing:—Sensibilities peculiarly touching connect the picture with its original. It was the very light which radiated from the hallowed brow, the identical gleam which lighted up the speaking eye, the pallid hue which hung upon the marble cheek, that pencilled the cherished image, and fixed themselves for ever there.”

Fig. 3.

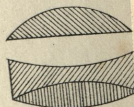
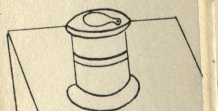
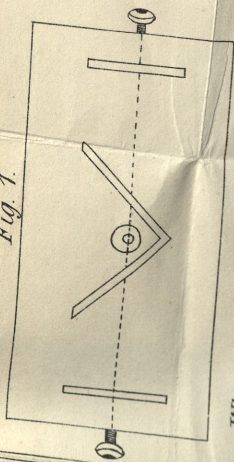
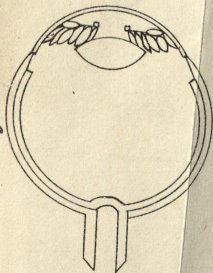


Fig. 1.



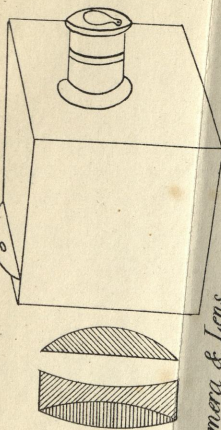
Wheatstone's Reflecting Stereoscope

Fig. 2



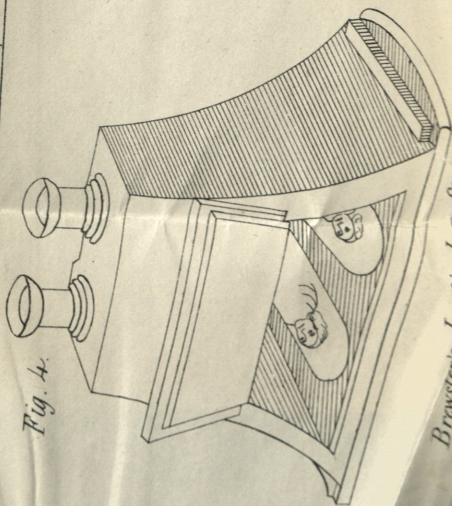
Section of Human Eye

Fig. 3.



Camera & Lens

Fig. 4.



Brewster's Lenticular Stereoscope.

Fig. 5.



Pair of Busts for Lenticular Stereoscope.

Fig. 10.

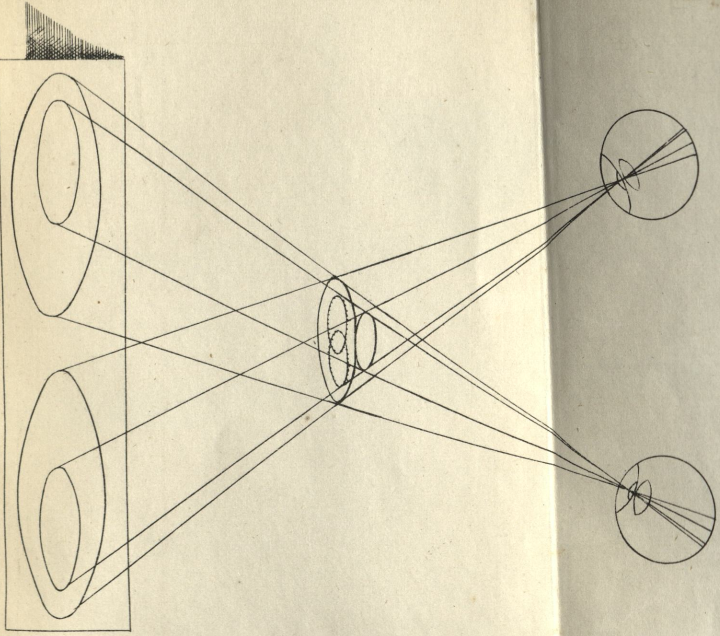


Fig. 6.

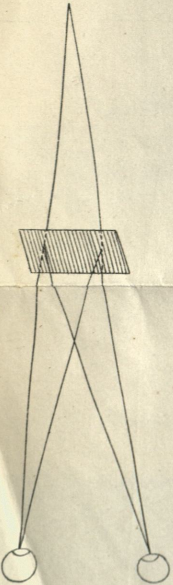


Fig. 7.

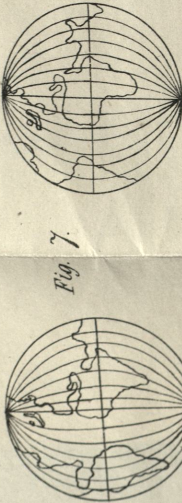


Fig. 8.

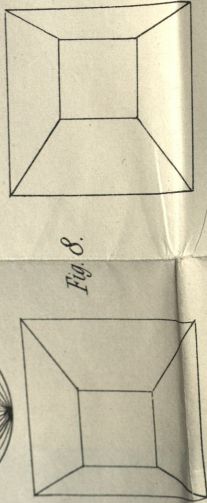
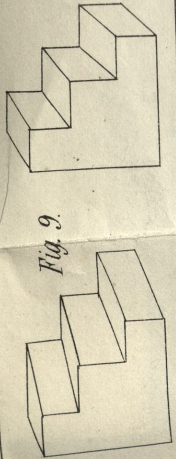
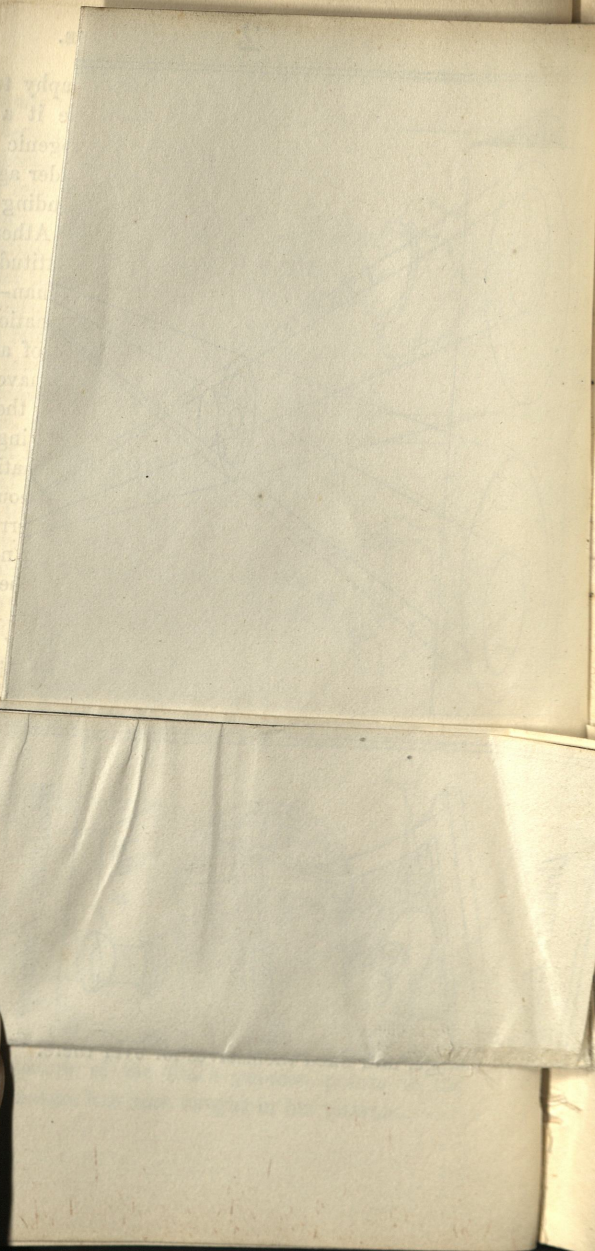


Fig. 9.



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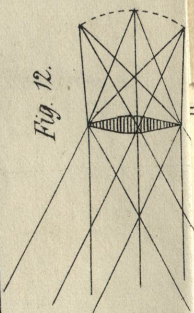
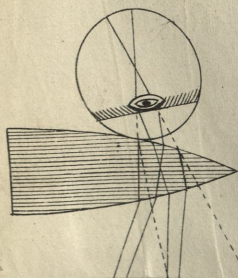


Fig. 12.

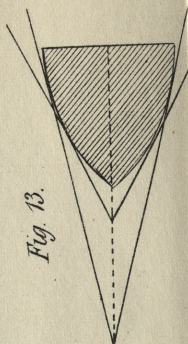


Fig. 11.

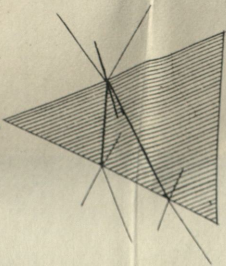


Fig. 12.

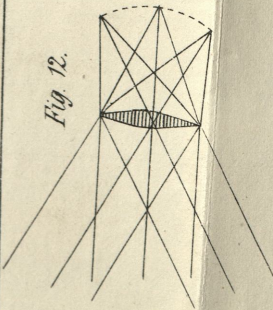


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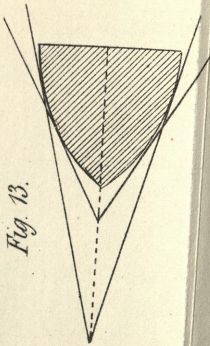


Fig. 14.

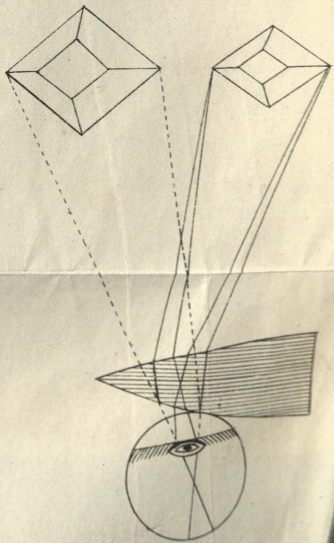


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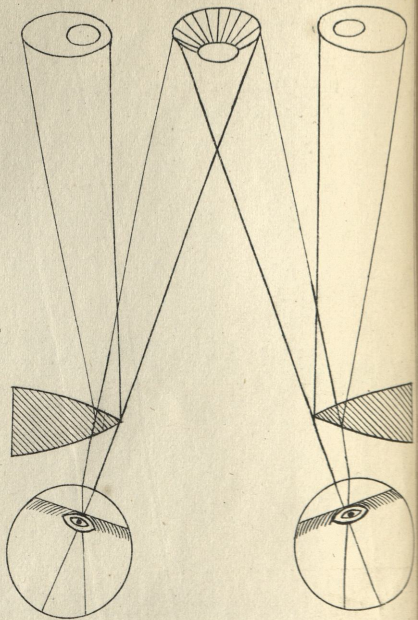
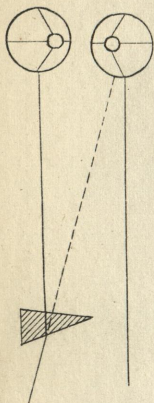
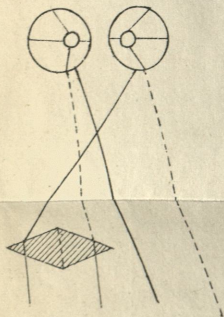
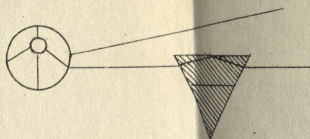
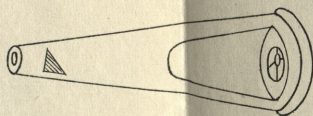
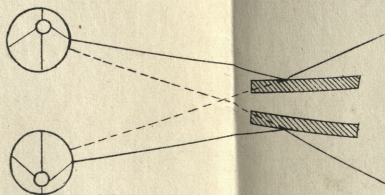
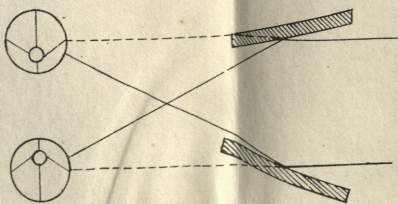
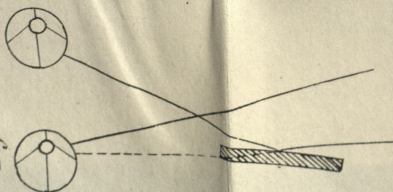


Fig. 16.*Fig. 17.**Fig. 22.**Fig. 21.**Fig. 20.**Fig. 19.**Fig. 18.*

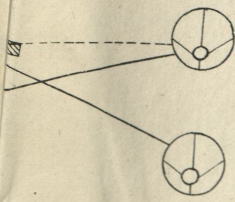


Fig. 18.

